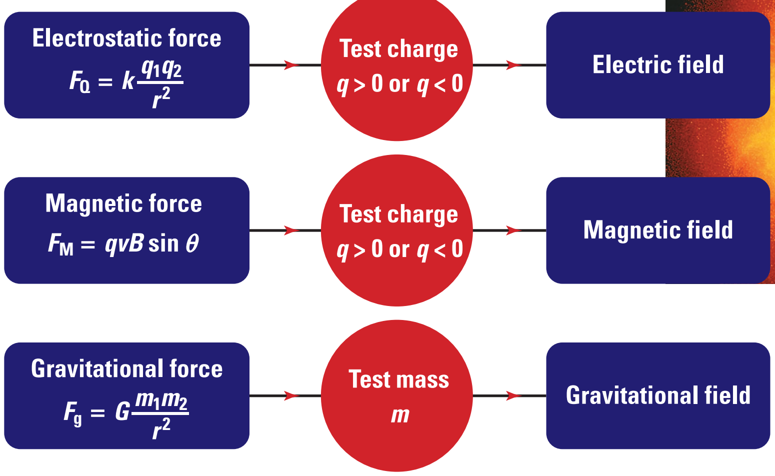
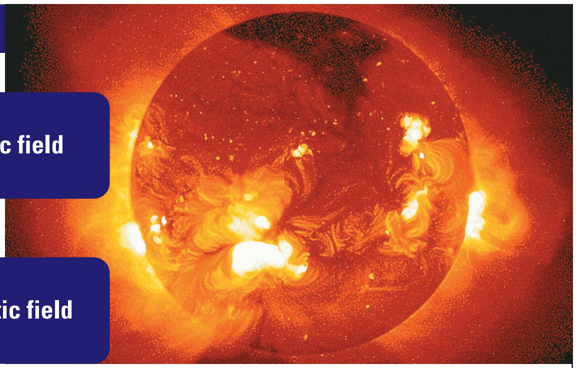
CHAPTER 8 Review

REFLECTING ON CHAPTER 8

- The electric field pattern for a collection of charges can be generated by considering the field vectors due to each individual charge.
- Electric field lines leave a positive charge and/or enter a negative charge and are always perpendicular to the surface of a conductor.
- The number of field lines is proportional to the magnitude of the net charge.
- Equipotential surfaces are always perpendicular to the electric field lines
- The electric field is uniform between two oppositely charged parallel plates placed close together.
- The magnitude of the electric field between parallel plates is proportional to the charge density on the plates.
- The magnitude of the electric field intensity between parallel plates is given by the equation $\vec{E} = \frac{\Delta V}{\Delta d}$.
- The potential gradient describes the linear change in electric potential difference at positions between the plates.
- Electric fields can be used to transfer kinetic energy to charged particles, so that $qV = \frac{1}{2}mv^2$.
- An electric field can also be used to balance the force of gravity on a charged particle.
- The electron volt is an alternative unit for the energy of a charged particle.
- The charge on the electron was determined by Robert Millikan by measuring the terminal velocities of oil drops placed between a parallel plate apparatus.
- The drift velocity of the electrons in a conductor carrying a current is very slow, compared with the speed of the current itself.
- The Faraday ice-pail experiment demonstrated that the net charge inside a hollow conductor is zero; all charge resides on the outer surface.
- Faraday shielding is a useful way of preventing external electromagnetic interference in circuit components.
- The magnetic force on a charged particle travelling in a magnetic field is $F_M = qvB\sin\theta$ and its direction is described by a right-hand rule.

Concept Organizer





Solar flares are a result of the build up and then release of magnetic energy. Electrons, protons and nuclei are accelerated into the solar atmosphere. An amount of energy equivalent to millions of 100 Mt bombs is released.

- The magnetic force on a conductor carrying a current in a magnetic field is $F_M = IlB \sin \theta$ and its direction is described by a right-hand rule.
- A magnetic field can be used to cause the circular motion of a charged particle, so that $qvB = \frac{mv^2}{r}$.
- The velocity of a charged particle can be determined by electric and magnetic fields.
- The motion of a charged particle under the action of electric and/or magnetic fields forms the basis for applications such as cyclotrons, synchrocyclotrons, and mass spectrometers, among others.
- The containment of a plasma in a Tokamak fusion reactor is achieved through magnetic fields.

Knowledge/Understanding

1. Answer the following questions about Millikan's oil-drop experiment.
   (a) Describe the main features of the experiment.
   (b) What were the results of the experiment and their significance?
   (c) Draw free-body diagrams of an oil drop that is between two horizontal, parallel electrically charged plates under three conditions: the oil drop is stationary, the oil drop is falling toward the bottom plate, the oil drop is drifting upward.
   (d) What was the effect of Millikan's use of X rays in his experiment?
   (e) Explain why the plates in the experiment need to be horizontal.
2. Imagine that you are probing the field around a charge of unknown magnitude and sign. At a distance r from the unknown charge, you place a test charge of q_1. You then substitute q_1 with a second test charge, q_2, that has twice the charge of $q_1 (q_2 = 2q_1)$.
   (a) Compare the forces that would act on the two test charges.
   (b) Compare the electric field that would affect the two test charges.
3. State mathematically and describe in words the definition of a tesla.
4. Can the magnetic force change the energy of a moving charged particle? That is, can the magnetic force do work on the particle?
5. (a) What is the function of the alternating potential difference in a cyclotron? The potential difference is applied across which two parts of the cyclotron? Why does the potential difference have to alternate in polarity?
   (b) What is the function of the magnetic field in a cyclotron? Is the magnetic field constant or alternating in direction?
6. Mass spectrometers are used to determine the masses of positively charged atoms and molecules.
   (a) Draw a concept map of the physics principles on which mass spectrometers were developed.
   (b) Explain the function of a velocity selector when it is used in conjunction with a mass spectrometer.
7. What types of studies were conducted to probe atomic structure prior to the development of particle accelerators? What were the limitations of such studies for developing an understanding of the micro-world?
8. Contrast the designs of particle accelerators that accelerate particles linearly and those that accelerate particles in circular paths. What are the advantages and disadvantages of each design?

Inquiry

9. Research and make a model of one type of particle accelerator that is being used currently. Your model should include all critical components and show their relationship with each other. Write a report to describe the physics involved in the accelerator's operation.

10. Suppose a cyclotron that normally accelerates protons is now to be used with alpha particles. What changes will have to be made to maintain synchronism?

11. Write a proposal for a new experimental facility to study the structure of the atom. Evaluate different particle accelerators and make a case for why you want to use a particular design. Include a cost analysis in your proposal. What are the most expensive components?

Communication

12. Use the rules of electric field line formation to explain why the lines around a negatively charged sphere are uniformly spaced and directed radially inward.

13. Outline, using vector diagrams, why the electric field at any point between two parallel plates is uniform and independent of the distance between the plates.

14. Consider a large, positively charged sphere. Two positively charged objects, A and B, are the same distance away from the sphere. Object A has a charge three times as large as that of object B. Which property will be the same for the two objects, the electric potential energy or the electric potential difference? Which property will be three times as large for object A compared to object B, the electric potential energy or the electric potential difference?

15. A proton passes through a magnetic field without being deflected. What can be said about the direction of the magnetic field in the region? Draw a sketch to illustrate your reasoning.

16. An electron is moving vertically upward when it encounters a magnetic field directed to the west. In what direction is the force on the electron?

17. Consider two parallel current-carrying wires. If the currents are in the same direction, will the force between the wires be attractive or repulsive? If the currents are in opposite directions, will the force between the wires be attractive or repulsive? Draw sketches to illustrate your answers.

18. A simple particle accelerator consists of three components. Make a sketch that identifies each component and its function. Why must ions be used instead of neutral particles?

Making Connections

19. A television uses a cathode ray tube to direct a beam of electrons toward a screen.
    - **(a)** Draw a schematic diagram of a television picture tube as seen from the side and explain how electric and magnetic fields are used to accelerate and deflect the electrons.
    - **(b)** Although electrons do not orbit in the magnetic field of a television cathode ray tube, their trajectory does follow a definable circular arc. On your diagram, label where this circular arc is located and explain how the radius of the arc can be used to determine the size of the picture tube.

20. The origins of naturally occurring magnetic fields are still poorly understood. Outline theories that explain the origin of Earth's magnetic field, the Sun's magnetic field, and the magnetic field of the Milky Way galaxy. Explain how these theories can be tested.

21. Although the cause of Earth's magnetic field is uncertain, it is known to be unstable. Analysis of rock strata in Earth's crust suggests Earth's magnetic field has reversed itself several times over the past five million years. How is this analysis done? What is the current thinking on why this occurs?

Problems for Understanding

22. The electric field intensity between two large, charged parallel plates is 400 N/C. If the plates are 5.0 cm apart, what is the electric potential difference between them?

23. Two parallel charged metal plates are separated by 8.0 cm. Identify four points along a line between the plates, A, B, C, and D, located at the following distances from the negatively charged plate: 0.0 cm, 2.0 cm, 4.0 cm, and 6.0 cm. The electric potential difference at point B, V_B, is measured to be 40.0 V.

(a) What is the electric potential difference across the plates?
(b) What is the electric potential difference at points A, C, and D?
(c) What is the potential difference between points A and B, B and C, and A and D?
(d) What is the electric field strength between the plates?
(e) A 1.0 μC test charge is placed first at point B, then at point C. What force does it experience at each point?
(f) Repeat (e) above for a 2.0 μC test charge.

24. In a Millikan oil-drop experiment, an oil drop of unknown charge is suspended motionless when the electric field is 3500 N/C. If the upper plate is positive and the drop weighs 2.8×10^{-15} N, determine **(a)** the charge on the oil drop and **(b)** the number of excess or deficit electrons on the oil drop.

25. A pith ball has a charge of −5.0 nC. How many excess electrons are on the pith ball?

26. A 10.5 cm wire carries a current of 5.0 A. What is the magnitude of the magnetic force acting on the wire if the wire is perpendicular to a uniform magnetic field of 1.2 T?

27. A small body moving perpendicular to a magnetic field of 0.25 T carries a charge of 6.5 μC. If it experiences a sideways force of 0.52 N, how fast is it travelling?

28. Consider a horizontal, straight 2.0 m wire carrying a 22 A current that runs from west to east. If the wire is in Earth's magnetic field, which points north with a magnitude of 4.0×10^{-5} T, calculate
(a) the magnetic force on the wire
(b) the maximum mass of the wire that would be supported by Earth's magnetic field

29. A velocity selector consists of an electric field of 20 000 V/m (2.0×10^4 V/m) perpendicular to a magnetic field of magnitude 0.040 T. A beam of ions, having passed through a velocity selector, is passed into a mass spectrometer that has the same magnetic field. Under these conditions, the radii of curvature of the path of singly charged lithium ions is found to be 78 cm. Calculate the mass of the lithium ions.

30. The period of a charged particle's circular orbit in a uniform magnetic field can be calculated from the radius of its orbit and its tangential velocity. Interestingly, both the period and its inverse, the frequency, are independent of the particle's speed and the radius of its orbit. Consider two electrons moving perpendicular to a 0.40 T magnetic field. One has a speed of 1.0×10^7 m/s and the other has a speed of 2.0×10^7 m/s.
(a) Calculate the radii of the orbits of the two electrons.
(b) Calculate their periods.
(c) Calculate their frequencies.
(d) Comment on the above results.

31. Suppose an electron and a proton are each injected perpendicularly into a uniform magnetic field with equal kinetic energies.
(a) Compare the periods of their orbits.
(b) Compare the radii of their orbits.

32. Charged particles from the Sun can be trapped by the magnetic field that surrounds Earth. If the particles enter the atmosphere, they can excite atoms in the air, resulting in the phenomenon of auroras. Consider a proton with a speed of 1.2×10^7 m/s that approaches Earth perpendicular to Earth's magnetic field. It is trapped and spirals down a magnetic field line.
(a) If the magnetic field strength at the altitude where the proton is captured is 2.0×10^{-5} T, calculate the frequency and radius of curvature of the proton's orbital motion.
(b) Repeat (a) for a proton that comes in at half the speed of the first proton.

33. An electron moves with a velocity of 5.0×10^6 m/s in a horizontal plane perpendicular to a horizontal magnetic field. It experiences a magnetic force that just balances the gravitational force on the electron.
(a) Calculate the strength of the magnetic field.
(b) If the electron is travelling north, what is the magnetic field direction?